TPF Terrestrial Planet Finder

Science Objectives of the TPF Coronagraph

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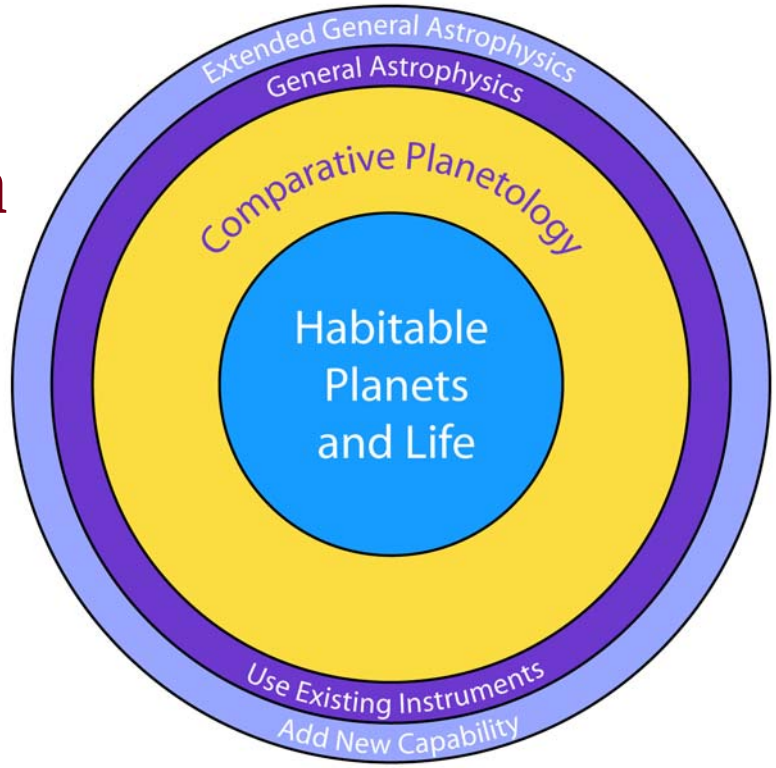

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TPF-C Science Objectives

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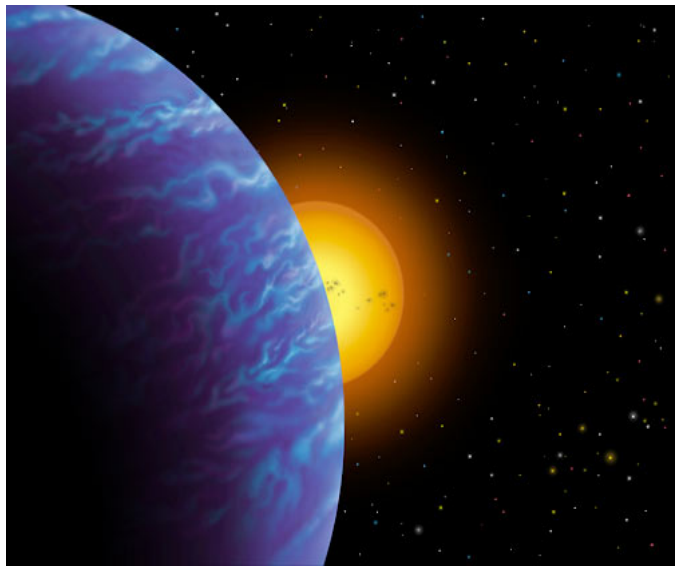
Terrestrial Planets Detection and Characterization



1) Search for and directly detect **terrestrial planets** that may exist in the habitable zone around nearby stars

2) Characterize the atmospheres of these planets in search for **signatures of biological activity**

Comparative Planetology

3) Direct detection and characterization of the **other constituents of planetary systems**

General Astrophysics

4) Carry out a program of revolutionary **general astrophysics** investigations

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Core Science Objectives

Directly detect and characterize Earth-like planets in habitable zone around nearby stars

- **Direct detection** - *must separate planet light from star light*
- **Planet characterization** - *must determine type of planet, its gross physical properties and atmosphere constituents* allowing *assessment of likelihood of life*

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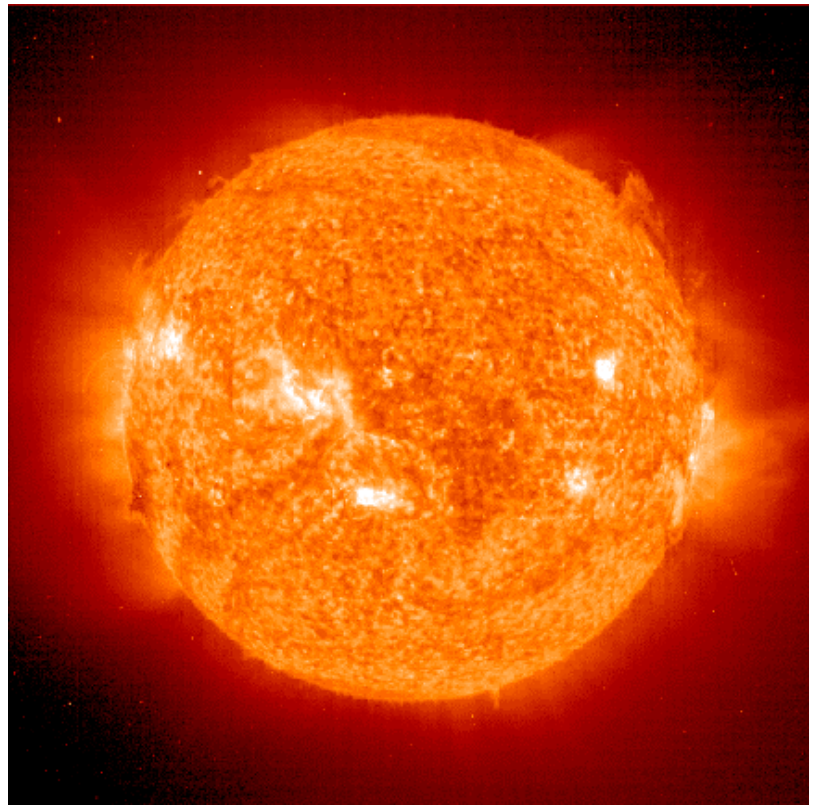
Types of Target Stars

On astrophysical grounds, Earth-like planets should be found around stars that are roughly similar to the sun.

Therefore TPF target stars should include main sequence **F, G, and K** stars.



To be drawn from a complete ~25 pc distance limited sample (Hipparcos). See for example the database at http://sco.stsci.edu/tpf_tldb/.

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Number of Target Stars

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Number of Stars to Search. We require TPF-C to search at least 35 ***core stars***, with a goal of searching at least 165 stars (35 core stars ***plus 130 additional stars***).

Extended Number of Stars. We desire to search as many stars as possible, beyond the required core and additional star groups. We anticipate that any mission capable of satisfying the requirements will also be capable of searching many more stars if the requirements are relaxed. Therefore we desire that the mission search an ***extended group of stars*** defined as those systems ***of any type*** in which all or part of the continuously habitable zone (see below) can be searched.

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Terrestrial Planets Defined

TPF must be able to detect terrestrial planets larger than 1/2 Earth surface area and having Earth albedo.

- ***Habitable Zone*** - range of orbits where life is possible on a terrestrial type planet. This implies conditions where liquid water may exist over geologically significant time. In the Solar system, HZ is between orbits of Venus and Mars, i.e. **0.7-1.5 AU**. For other stars HZ scales with square root of luminosity. The minimum terrestrial planet must be detectable on the outer edge of the HZ.
- ***Orbital Phase Space*** - TPF-C must be designed to search for planets drawn from a uniform probability distribution in semi-major axis over the HZ and in eccentricity over the range **0-0.35**, with the orbit pole uniformly distributed over the celestial sphere with random orbit phase

The inner and outer boundaries that define the habitable zone is an ongoing subject of discussion in the STDT

Required Search Completeness

Search Completeness. Search completeness is defined as that fraction of planets in the orbital phase space that could be found within instrumental and mission constraints.

We require each core stars to be searched at the 90% completeness level.

For the additional stars stated as a mission goal, the required 90% completeness is integrated over the additional stars.

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Measurement of Planet Color

Color. Colors distinguish planets from other objects. TPF must use color to characterize the type of planet and to measure its gross properties, including effective temperature at mid-IR wavelengths. Reference colors and relative magnitudes are those of Venus, Earth, Mars, and Jupiter.

TPF must measure planet color in **3 or more bands** (wavelengths and bandwidth TBD), to an accuracy of 10%, for any detected planet.

We require that the ratio of color-characterized planets to all detected planets have an expectation value of at least 50%.

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Measurement of Biomarkers Defined

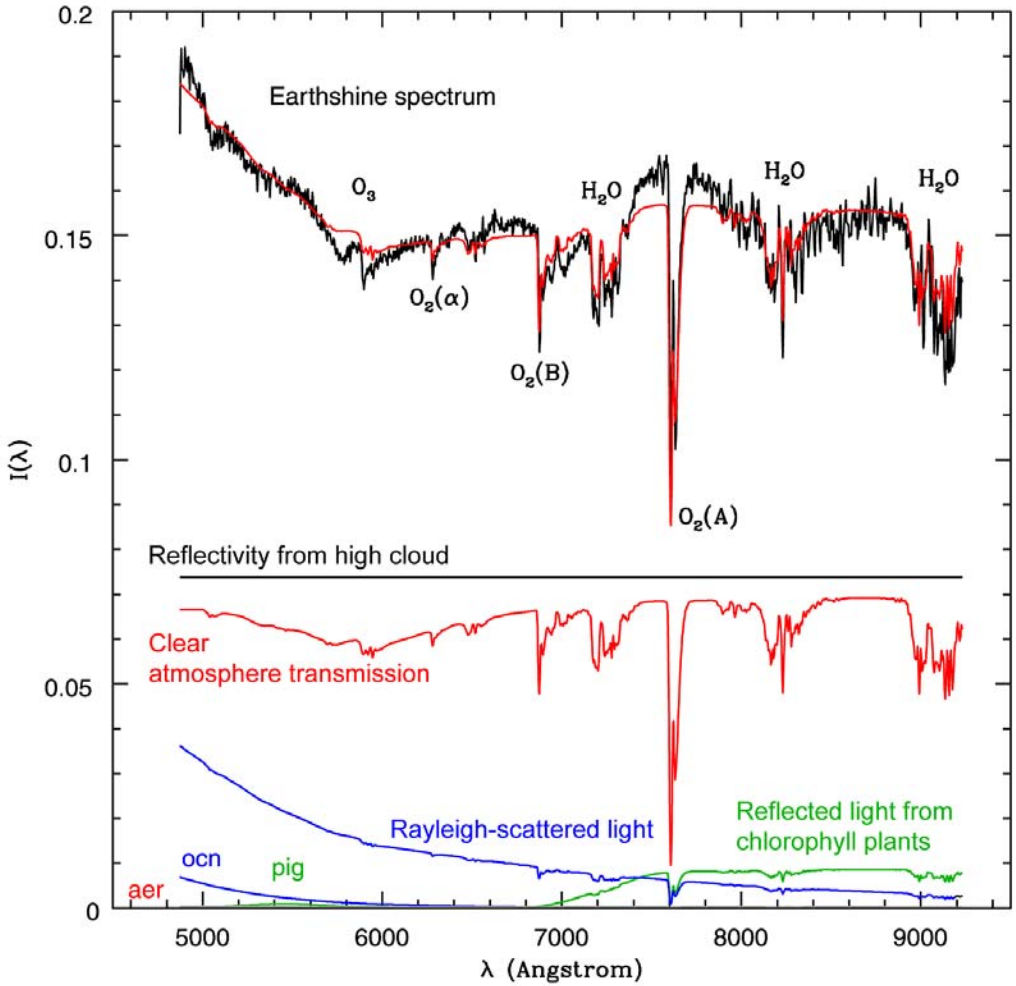
Spectrum. TPF-C must use the spectrum of a planet to characterize its surface and atmosphere. The spectrum of the present Earth, scaled for semi-major axis and star luminosity, must be used as a reference.

In this context, a measurement of a species is defined as the determination of the equivalent width of a spectral feature of that species to 20% accuracy.

Spectral Range and Resolution

Spectral Range. The required spectral range of TPF-C is **0.5 to 0.8** microns in the visible, measured with a spectral resolution of **70**.

The desired range is 0.5 to 1.05 microns, measured with a spectral resolution of 140.



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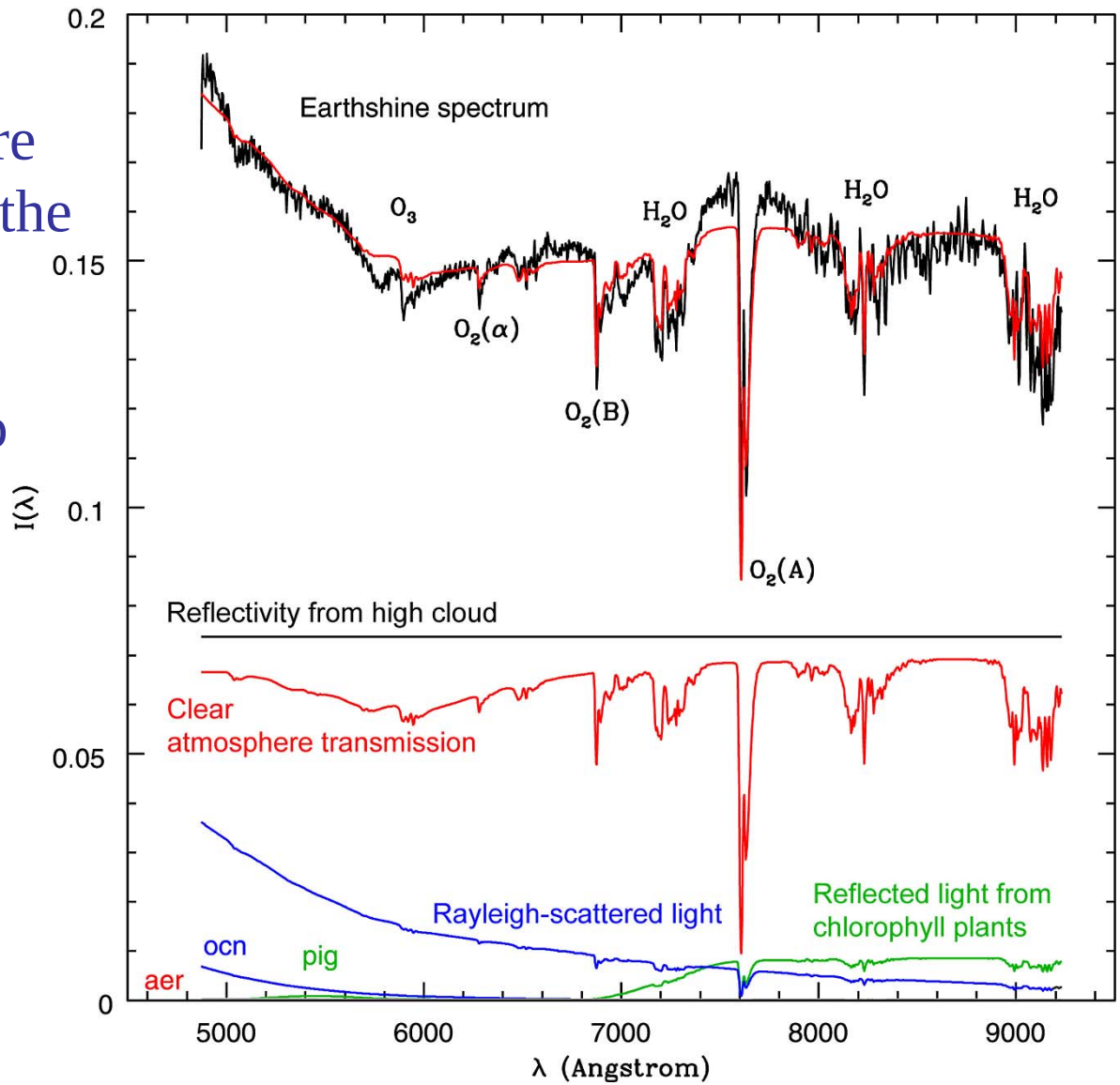
Biomarkers to be Measured

TPF-C must measure O_2, H_2O, and O_3 in the visible.

We desire TPF-C to measure Rayleigh scattering, photosynthetic pigments, CO_2, and CH_4 in the visible.



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Required Characterization Completeness

Characterization completeness. It will be difficult to obtain spectra of the fainter or less well positioned planets.

We require that the ratio of spectrally-characterized planets to all detected planets have an expectation value of at least 50%.

Revisits

Visitations. Multiple visits per star may be required to achieve completeness or to study a planet along its orbit, to determine its orbit, distinguish it from background objects, and validate a measurement.

Therefore **TPF must make enough visits to meet the completeness and other requirements**.

Giant Planets

Giant Planets. The occurrence and properties of giant planets may determine the environments of terrestrial planets.

We require the TPF field of view and sensitivity must be sufficient to detect a giant planet with the **radius and geometric albedo or effective temperature of Jupiter at 5 AU** (scaled by the square root of stellar luminosity) around at least 50% of its target stars.

A signal-to-noise ratio of at least 5 is required.

Exozodiacal Dust

Exozodiacal Dust. Determining and understanding the properties of the zodiacal cloud is essential to understanding the formation, evolution, and habitability of planetary systems.

TPF must be able to detect planets in the presence of zodiacal clouds at levels up to **10 times** the brightness of the zodiacal cloud in the solar system.

No Other Constraints

Other constraints: Other than those specified above or in the table which follows, no other properties (e.g. metallicity or variability) of stars should be used to impose requirements on the TPF mission.

"*True wisdom is to know what is best worth doing and to do what is best worth doing.*"

—Edward Porter Humphrey.

Summary Table: Part I

Key Parameter	Requirement	Goal*
Star types (main sequence)	F through K	Others in extended list
Habitable zone	0.7 to 1.5 AU scaled by $L^{0.5}$	
Orbit phase space	Semi-major axis: uniform inclination: uniform eccentricity: 0–0.35	
Number of core stars to be searched	35 core stars	
Completeness per core star	90%	
Number of additional stars to be searched	(Not specified)	130 (F through K) + an extended list
Completeness per set of additional stars	(Not specified)	90% integrated over the ensemble of 165 stars (core and additional)
		*Stated in addition to the requirements already noted.

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Summary Table: Part II

Key Parameter	Requirement	Goal*
Minimum planet area	1/2 Earth area	
Geometric albedo	Earth	
Flux ratio	At least 3 broad wavelength bands;	
Spectral range	0.5–0.8 μm	0.5–1.05 μm
Spectral resolution	70	140
Biomarkers	O_2, O_3, and H_2O	Rayleigh scattering, photosynthetic pigments, CO_2, and CH_4
Characterization completeness	50%	
Giant planets	Jupiter brightness at 5 AU scaled by $L^{0.5}$, 50% of stars	
Average (Maximum) tolerable exozodi	3 (10) zodi	

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Back-up slides

Science Requirement Summary

TPF-C must be able to detect planets with half the area of the Earth, with the Earth's geometric albedo or the equivalent equilibrium effective temperature, searching the entire HZ of the core-group stars with 90% completeness per star.

Flux ratios must be measured in 3 broad wavelength bands, to 10% accuracy, for at least 50% of the detected terrestrial planets.

The spectrum must be measured for at least 50% of the detected terrestrial planets to give the equivalent widths of O_2, H_2O, and O_3 in the visible to an accuracy of 20%.

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Science Goal Summary

The goal for TPF-C is to be able to detect planets with half the area of the Earth, with Earth's geometric albedo, searching the entire HZ of the 35 core-group stars plus the aggregated HZs of at least 130 additional stars with 90% completeness for both groups.

Flux ratio must be measured in 3 broad wavelength bands to 10% accuracy for at least 50% of the detected terrestrial planets.

The spectrum must be measured for at least 50% of the detected terrestrial planets to give the equivalent widths of O_2, H_2O, and O_3 in the visible to an accuracy of 20%. We further desire that TPF-C measure Rayleigh scattering, photosynthetic pigments, CO2, and CH4 in the visible.

Further, we desire that the mission search an extended group of stars defined as those systems of any type in which all or part of the Habitable Zone can be searched.

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Meeting Agenda

Terrestrial Planet Finder

TPF

TPF-C ICS Pre-Proposal Workshop Agenda

Lowes L'Enfant Plaza Hotel, Washington, DC
480 L'Enfant Plaza, SW
Renoir Room, 2nd Floor
March 18, 2005

Agenda - Draft 2.0

Start	Duration	Friday, March 18	Speaker
8:00 AM	0:30	*Coffee*	
8:30 AM	0:15	Welcome address and meeting logistics	Tsvetanov/NPRS
8:45 AM	0:15	Purpose of TPF-C ICS NRA	Tsvetanov
9:00 AM	0:00		
9:00 AM	0:30	**Science Goals**	Tsvetanov/Lawson
9:30 AM	0:00	**Flight Baseline Concept**	
9:30 AM	0:15	Mission, orbit, launch vehicle	Lisman
9:45 AM	0:15	Spacecraft - power, data rate, pointing	Lisman
10:00 AM	0:15	Payload System Desciption	Lisman/Ford
10:15 AM	0:15	Optical Telescope Assembly	Ohl
10:30 AM	0:15	Facility Starlight Supression System	Mouroulis
10:45 AM	0:00		
10:45 AM	0:15	*Break*	
11:00 AM	0:00		
11:00 AM	0:00	**Proposal Guidelines**	
11:00 AM	0:20	General proposal requirements and evaluation criteria	Tsvetanov/Ford/Amed
11:20 AM	0:20	Additional proposal information and evaluation criteria	Tsvetanov/Ford/Amed
11:40 AM	0:20	Study deliverables - instrument design, performance, modeling	Tsvetanov/Ford/Amed
12:00 PM	0:00		
12:00 PM	1:30	*Lunch*	
1:30 PM	0:00		
1:30 PM	0:45	**Q & A**	Tsvetanov leads
2:15 PM	0:15	Recap and closing	
2:30 PM	0:00	**Adjourn**	